NDT AND RBI IN FUNCTION OF PRESSURE EQUIPMENT INTEGRITY LOSS

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Summary: *The paper presents examples of pressure equipment and pipelines the structural integrity loss of due to large induced defects in welded joints occurred during the time of preparation of construction or during operation, which are not detected in time or not at the time repaired, and can be attributed to inadequate prevention in system maintenance. Daily visual inspection should be provided in order to monitor the behavior of structures in exploitation, and if necessary, NTD together with RBI method of tesing should be applied to the most loaded parts of the structure. This approach may be applied to other types of similar construction, and its application in preventive maintenance would help extend the life of pressure equipment and pipelines.*

Keywords: *Non desctructive testing (NDT), Risic based inspection (RBI), Integrity loss, pressure equipment*

1. INTRODUCTION

According to the Pressure Equipment Directive PED 97/23/EC [1], the term "pressure equipment" includes vessels, piping, safety equipment and pressure devices, and in certain parts, flanges, fittings, supports. Directive PED 97/23/EC, applies to a wide range of products such as: pressure accumulator, heat exchangers, steam generators, industrial piping, safety devices, pressure accessories as well as flanges, nozzles, couplings, etc..
Such pressure equipment is widely used in the process industries (oil & gas, chemical, pharmaceutical, plastics and rubber and the food and beverage industry), high temperature process industry (glass, paper and board), energy production and in the supply of utilities, heating, air conditioning and gas storage and transportation. Due to its

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characteristics, this type of equipment requires special organization of monitoring in operation and maintenance system.
Continuous exploitation in very harsh environmental conditions can lead to relatively frequent failures of these structures. During the exploitation of pressure equipment and pipelines, under the effect of harsh environment and fatigue and thermal variable amplitude loading come to unexpected failures. These failures other than direct material damage, could jeopardize the safety of personnel. In addition, unanticipated delays in exploitation cause the damage, which is often much higher than the direct damage. High place among the causes of these failure takes inadequate exploitation and maintenance.
Directive PED 97/23/EC and Regulations on pressure equipment [1,2,3] define the legal limits for a detailed examination of the pressure equipment in order to assess the situation and preserve the integrity of construction vessels, piping and safety equipment.
In order to monitor the behavior of such structures and prevent the loss of structural integrity, preventive maintenance is very important, and it's related to the use of different control methods and testing, in particular NDT methods, as well as calculations arising from the results of inspection and testing. Lack of implementation of prevention leads to unpredictable loss of integrity of pressure equipment and piplines.

2. EXAMPLES OF INTEGRITY LOSS

Figure 1a shows the breakdown of steel water tower as a result of stormy weather and the wind, which was preceded by non-compliance with the specific conditions of exploitation, instructions for use and maintenance [4].

a) breaking the water tower at the root pole

b) through cracks in the steam pipe

Figure 1. Examples of loss of integrity of the water tower and steam lines

The thermal low cycle fatigue load on the steam line caused the fatigue failure of pipes and steam line leakage [5], fig. 1b. Drastic examples of the corrosion of the pipeline structure and the spherical tank are shown in fig. 2c and 2d [6,7].
These examples show that ISO 9000 standards haven't been respected, ISO 3834, EN 287 and EN 288 standards weren't properly applied and also independent accredited laboratory for testing of NDT methods did not confirm the results of NDT testing. Problems shown in these examples can be reduced considerably in similar constructions if we pay attention to: irregularity in the design, manufacture and operation, final quality

control before operation, properly defined control and testing, maintenance and repair during operation, qualification and certification of welding personnel who participates in the production, and later in the repair of damages of pressure equipment and piplines.

c) corrosion damage to pipelines

d) corrosion damage to the spherical tank

Figure 2. Examples of loss of integrity of the pipeline and spherical tanks for NH_3

3. CAUSES AND CONSEQUENCES OF INTEGRITY LOSS

During the operation period, fatigue of pressure equipment, pipelines and components may occur. The majority of the mechanisms and consequences of metal damage can be predicted on the basis of operational conditions. However, some of them are hard to detect and can cause serious damage in a short time, fig. 1a and 1b.
According to frequency of damage creation, causes are fatigue, ductile fracture and corrosion of materials. Such phenomena are based on errors in calculation, design and construction, errors in production and assembly, unexpected operating conditions and working environment.
After professional analysis of the results of inspection and testing damaged parts of pressure equipment and pipelines, the appropriate conclusions about the causes and consequences of failure could be performed.

4. CONTROL, NDT TESTING AND RBI APPROACH

Organization of the maintenance of such structures depends primarily on their size, shape, structure, number of employees and their professional experience in system maintenance and adequate database from maintaining and previous tests of similar structures. Daily visual inspection should be provided in order to monitor the behavior of structures in exploitation, and if necessary, NTD of testing should be applied to the most loaded parts of the structure. Due to the high risk of compromising the integrity of the equipment, it is necessary to apply new control approach based on risk, RBI (Risk Based Inspection). In order to minimize the potential loss of integrity of these structures, it is necessary to constantly monitor the situation and structural behavior through the control center system for monitoring, updating, detection and analysis of the measured

characteristic parameters. Based on the parameters the activities in a particular part of the design of pressure vessels and pipelines are defined.

Failure analysis in [4,5,6,7] and the conclusions are not sufficient to completely avoid manufacturing imperfections and ensure the integrity of welded pressure vessels and pipelines in exploitation. Directives, standards and recommendations for production of welded structures significantly contribute to solving the problem, but it cannot be completely eliminated because of its complexity and the large number of influencing factors. The damages could be identified during regular and special NDT testing with use of information technology standards, or by measuring the deformation at the macro or micro level [8]. For the purpose of prevention of integrity loss it is necessary to make 100% visual inspection, MT, PT, UT, in order to determine the material degradation and damages of components and structural parts of construction.

Other tests like penetrant testing (PT), radiographic testing (RT), and if necessary, control of hardness (HT) of welded joints and evaluation of microstructure by replica method (REP) can be used in order to get a reliable and useful results for determining the degree of integrity pressure vessels and pipelines and qualitative level of material degradation over the lifetime. RBI (Risk Based Inspection), is a system technique that helps users make business decisions regarding inspection and maintenance costs, reducing them significantly while increasing the reliability and availability of facilities. The risk is to consider the potential risks, while taking into account the probability of occurrence and consequences of an event. Risk can be defined as a combination of the probability of occurrence and the consequences of failure. This correlation is the result of a shift from "redundant inspections" of equipment that is not in critical condition (eg, new equipment and equipment operating in the relatively easier operating conditions) to increase inspection costs for components with potentially higher probability of failure and severe consequences (eg, old equipment and equipment operating in extremely harsh operating conditions). Dealing with the problem described above requires interdisciplinary knowledge from different fields - chemistry, engineering, physics, metallurgy and tribology. Only well organized and systematic approach as well as teamwork can lead to satisfactory results and reliable answers in order to prevent integrity loss. Program of inspection and testing of construction parts is defined based on the integrity loss prevention program. Reliable assessment of the integrity of the observed elements, could be made only after creation of adequate data base and the possibility of application of computer programs to the construction of pressure vessels and pipelines [9,10].

Database of implemented testing and research [11,12] on the appropriate structures allows us to analyze the behavior of supporting elements of pressure vessels and pipelines in order to determine changes in mechanical properties of materials.

Stress analysis, analysis of damage and fractures of welded joints and construction elements provide important directives for the development of design methods and construction elements of pressure vessels and pipelines to improve the properties of existing materials and their processing technologies. Also, by analyzing fractures, the development of new technical solutions and methods of testing is enabled in the prototype stage. It is necessary to take into account the risk analysis and structural integrity [13], as a new approach to the assessment of structural integrity.

Based on data collected from control, testing and analysis of damaged elements, control calculation of the critical parts of the constructionis made. Tipical calculation, should be illustrated with the calculation of static and dynamic stress analysis using the finite element method, FEM, to see the stress distribution due to the impact of the load in the present conditions. Control calculations confirm the existence or loss of structural integrity, and provides guidance for further action.

5. CONCLUSION

Inadequate maintenance of pressure vessels and pipelines in terms of protection entails a costly repair, and it is necessary to determine preventive measures and very thoroughly research issues of protection, durability and maintenance, especially critical parts of pressure vessels and pipelines in operation.
In relation to above stated, assessment of the state of the parts of pressure vessels and pipelines affected by outside influence is required. This should be followed by the NDT testing, in order to determine the actual extent of damage, and if necessary, appropriate measures of rehabilitating critical damages and material degradation should be taken. RBI provides a methodology for determining the optimal combination of methods, scope and frequency of inspection, and can be considered as a technique to optimize testing of equipment under pressure applying NDT methods.
Only by testing the pressure vessels and pipelines under working conditions makes it possible to assess their condition completely. During examination period, the necessary data are obtained to determine the quality and structural integrity assessment and evaluation of the impact of the elements on the capacity and is given the necessary data to establish the joint work of equimpent and structure.
In case of breakdown of equipment,t systematic testing, control, analysis and calculations are required. Then, on the basis of a program to determine the cause and consequence of damage, the appropriate conclusions in order to obtain new information for the following reliable design and construct pressure vessels and pipelines shoul be made.

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НДТ И РБИ У ФУНКЦИЈИ ГУБИТКА ИНТЕГРИТЕТА ОПРЕМЕ ПОД ПРИТИСКОМ

Резиме: *У раду су дати примери губитка интегритета конструкција посуда под притиском и цевовода изазваних грешкама у основном материјалу и завареним спојевима насталим још у време израде конструкције или у току експлоатације, које нису на време откривене или нису на време санирање, а могу се приписати неадекватној превенцији у систему одржавања. Праћење понашања оваквих конструкција у експлоатацији обезбеђује се свакодневним визуелним прегледима, а по потреби и испитивањима методама без разарања (ИБР) у корелацији технике инспекције базиране на ризику (РБИ) за најоптерећеније делове конструкције, а све у функцији превенције губитка интегритета. Дати приступ се може применити за различите типове сличних конструкција, а његова примена у превентивном одржавању би допринела продужењу радног века конструкција посуда под притиском и цевовода.*

Кључне речи: *Испитивање без разарања (ИБР), Инспекција базирана на ризику (РБИ), губитак интегритета, Опрема под притиском*